Flash-Type Discrimination

GOES-R3 Science Meeting
September 29, 2008
Huntsville, AL

Dr. William Koshak; NASA-MSFC
Dr. Richard Solakiewicz; Chicago State University

Data Mining

Historical Perspectives (Optical Pulses)

“We believe that it will be very difficult to discriminate reliably between CG and IC flashes from geostationary orbit, at least for the present generation of optical detectors.” **(Goodman et al., 1988)**

“ Some discrimination information can be found in the optical waveforms: for example, IC waveforms are often broader and more structured than CG waveforms. However, the bulk of the discrimination capability in the FORTE instruments seems to lie in the interpretation of the VHF spectrograms.” **(Suszcynsky et al., 2000)**

“… the identification of IC and CG events cannot be made on the basis of pulse width.” **(Kirkland et al., 2001)**

“First, it is not possible to discriminate between CG and IC lightning types based on the optical characteristics of peak power and effective pulse width.” **(Davis et al., 2002)**

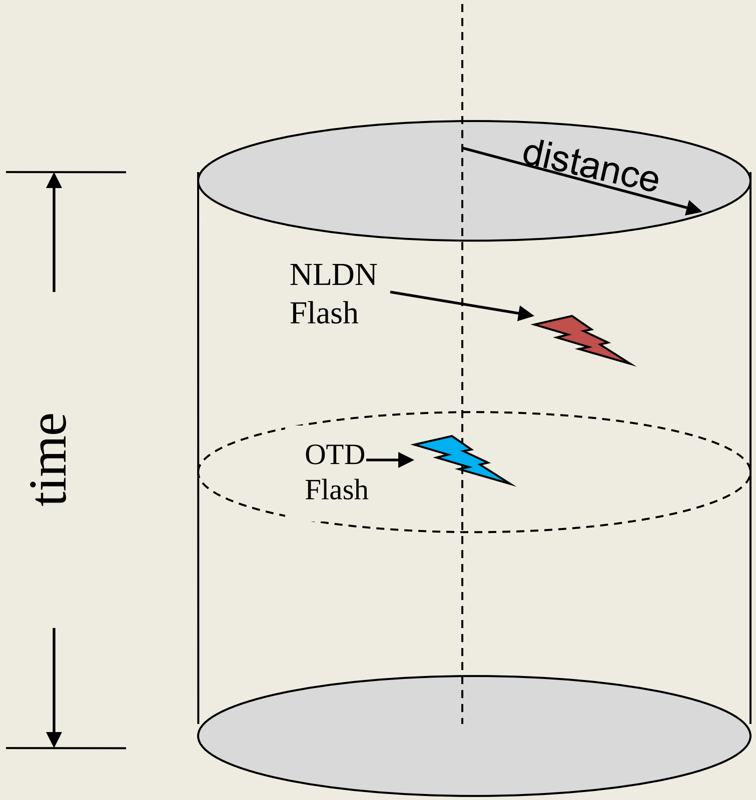
“Previous work by Suszcynsky et al. (2000) and Light et al. (2001) has established a robust technique for identifying lightning types using FORTE VHF spectrograms and power time series.” **(Davis et al., 2002)**

So Discriminating Flashes Using Optical Pulses is (thus far) like pulling teeth …

But, exploiting Optical Pulses not same thing as trying to exploit Cloud-Top Areal Emissions.

… So Partition OTD Flashes into CGs and ICs

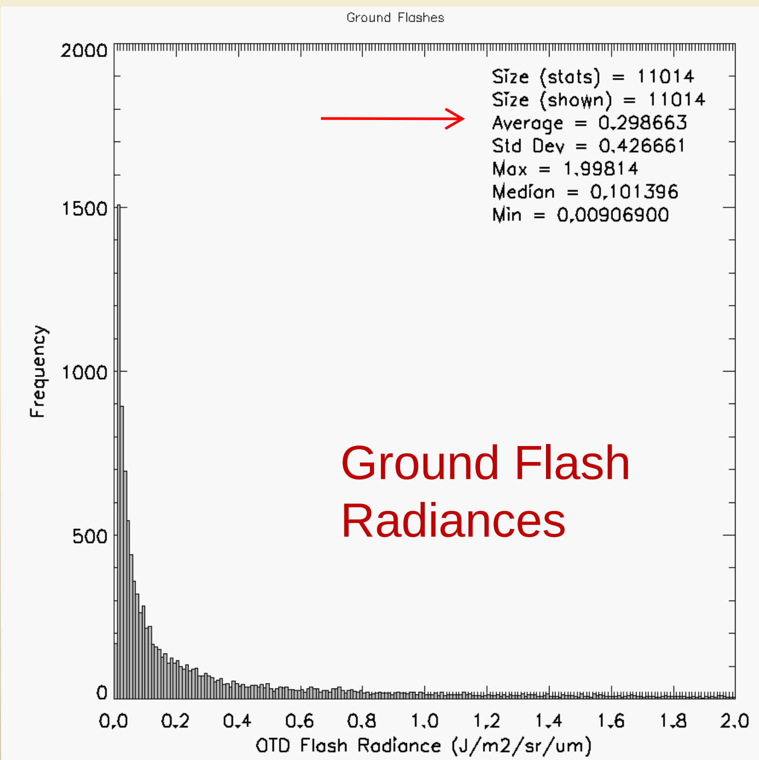
[using NLDN data]

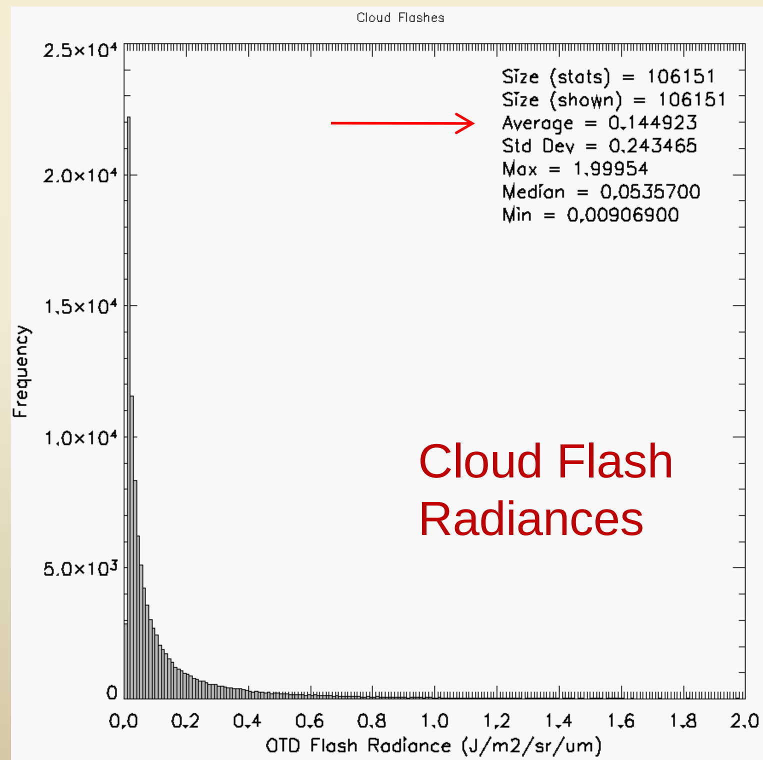


If NLDN flash inside cylinder, then OTD flash is deemed a Ground Flash.

But Results Have <u>Overlap</u> Making Discrimination Difficult

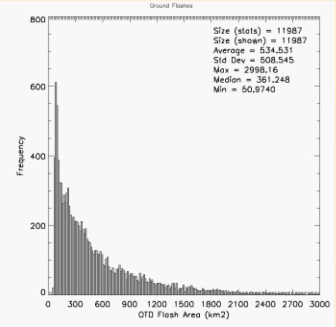
- Statistical evidence suggests that optical parameters of ground and cloud flashes are different on average, but the distributions overlap thus making discrimination difficult. See example below:

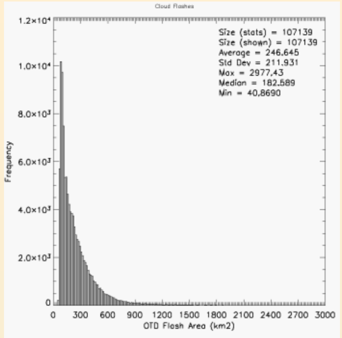




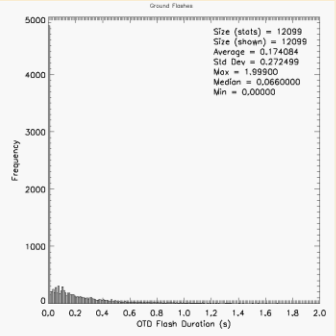
MORE OVERLAP

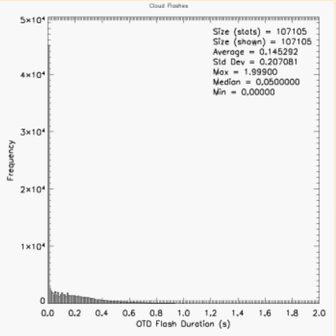
AREA



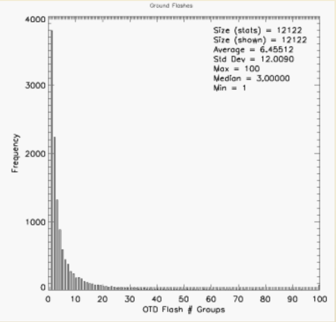


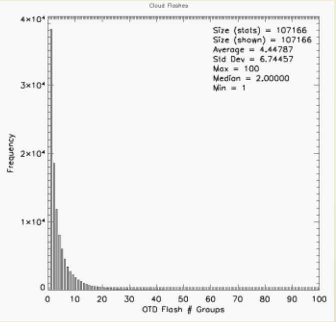
DURATION



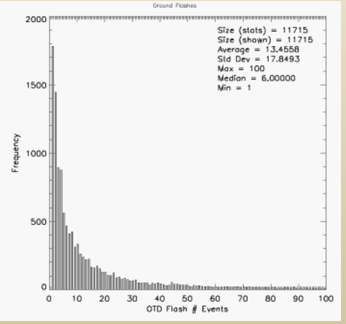


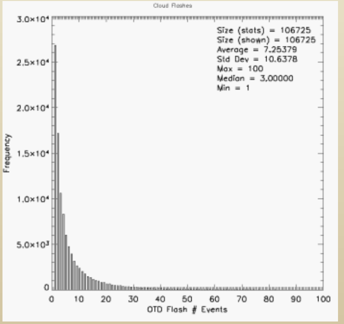
GROUPS





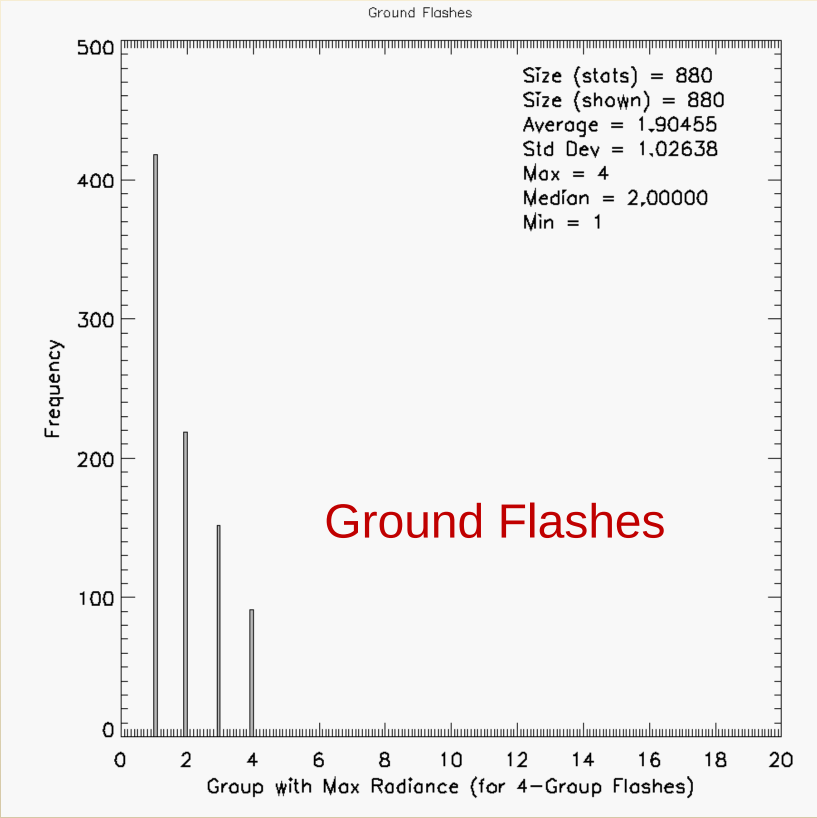
EVENTS

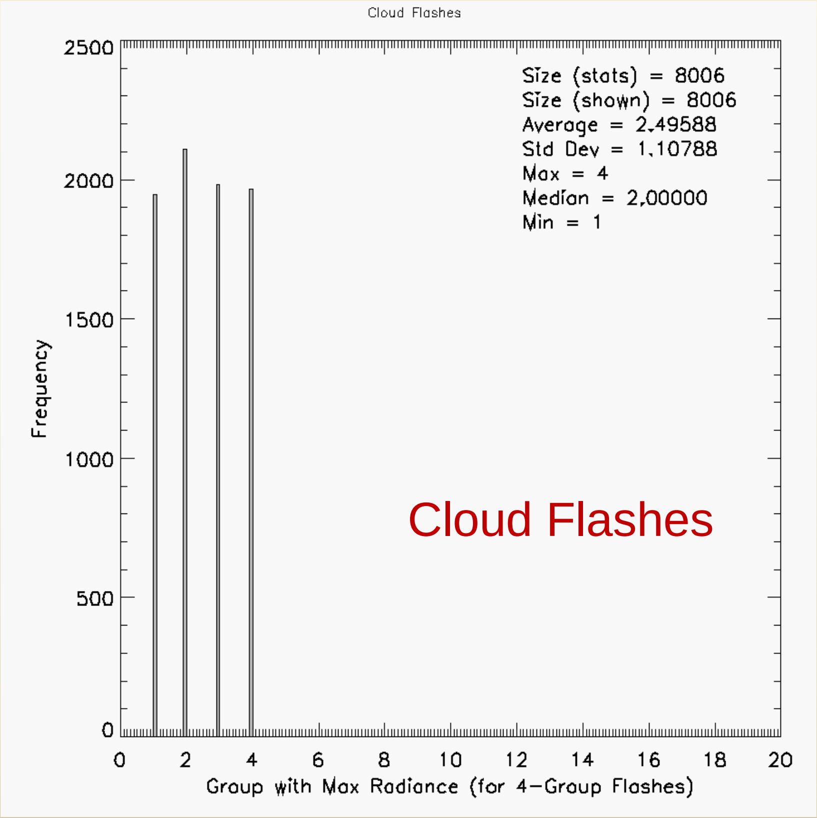




However: Group-level Analyses Might Help

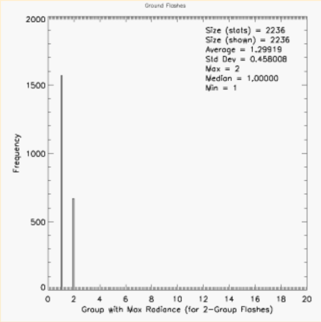
- 1st optical group of ground flashes is normally the brightest, but not so with cloud flashes. See 4-group flash examples below:

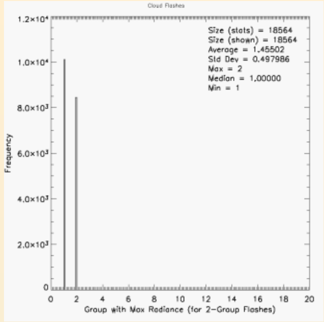




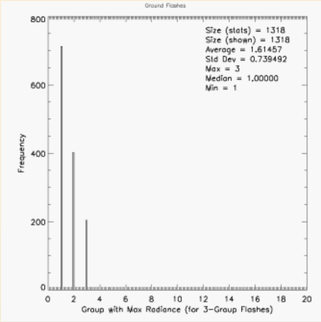
THE OTHERS

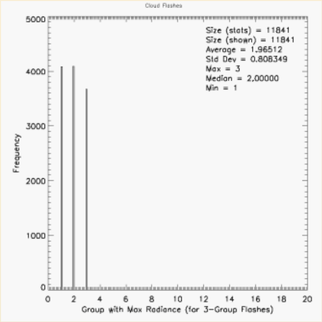
2-GROUP FLASHES



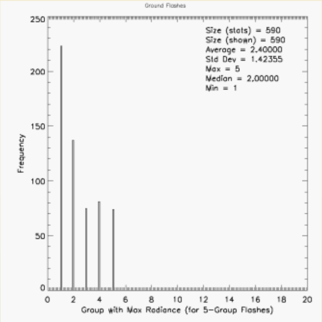


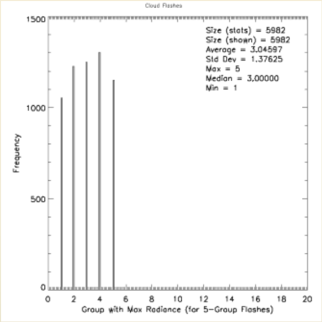
3-GROUP FLASHES



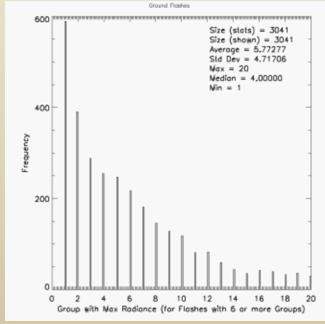


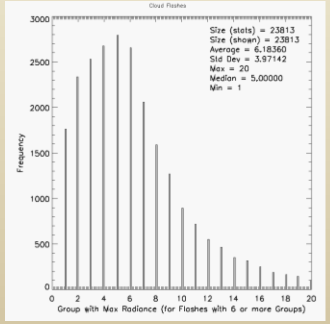
5-GROUP FLASHES





>= 6-GROUP FLASHES





Boltzmann Transport Modeling

(extension of Koshak et al., 1994)

Model Parameters

- Cloud Properties
  - Photon Mean Free Path (~ 16 meters)
  - Dimensions (10 km thick in altitude, horiz. varies)
  - Geometry (rectangular parallelpiped, cylindrical)
  - Altitude (cloud base = 3 km, cloud top = 13 km)
- Lightning Channel Properties
  - Current (4 kA for IC, 40 kA for CG)
  - Location/Geometry within Cloud (vertical lines as shown)
  - Length (4 km for IC, 7 km for CG)
  - Wavefront Propagation Direction (up for both IC and CG)
  - Wavefront Propagation Speed (10^7 m/s for IC, 10^8 m/s for CG)
  - Source brightness decay with Altitude (Jordan et al., 1997)

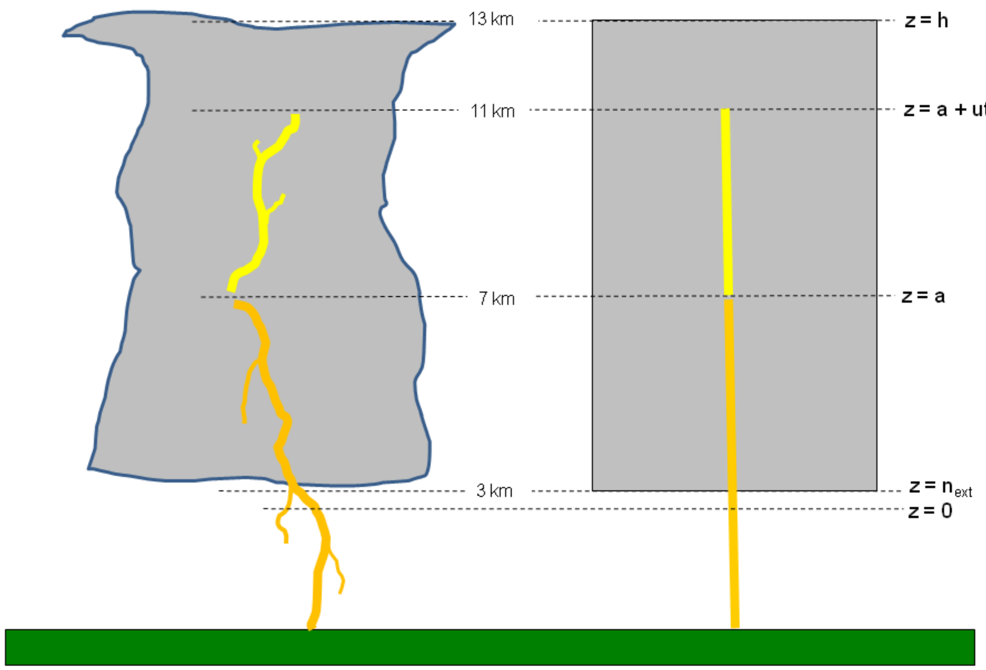


Figure 1. A ground flash and an intracloud flash (left) and an idealized model (right). We consider only a single stroke within the ground flash. The extrapolation distance n_{ext} is exaggerated for clarity.

Cloud-top Integration

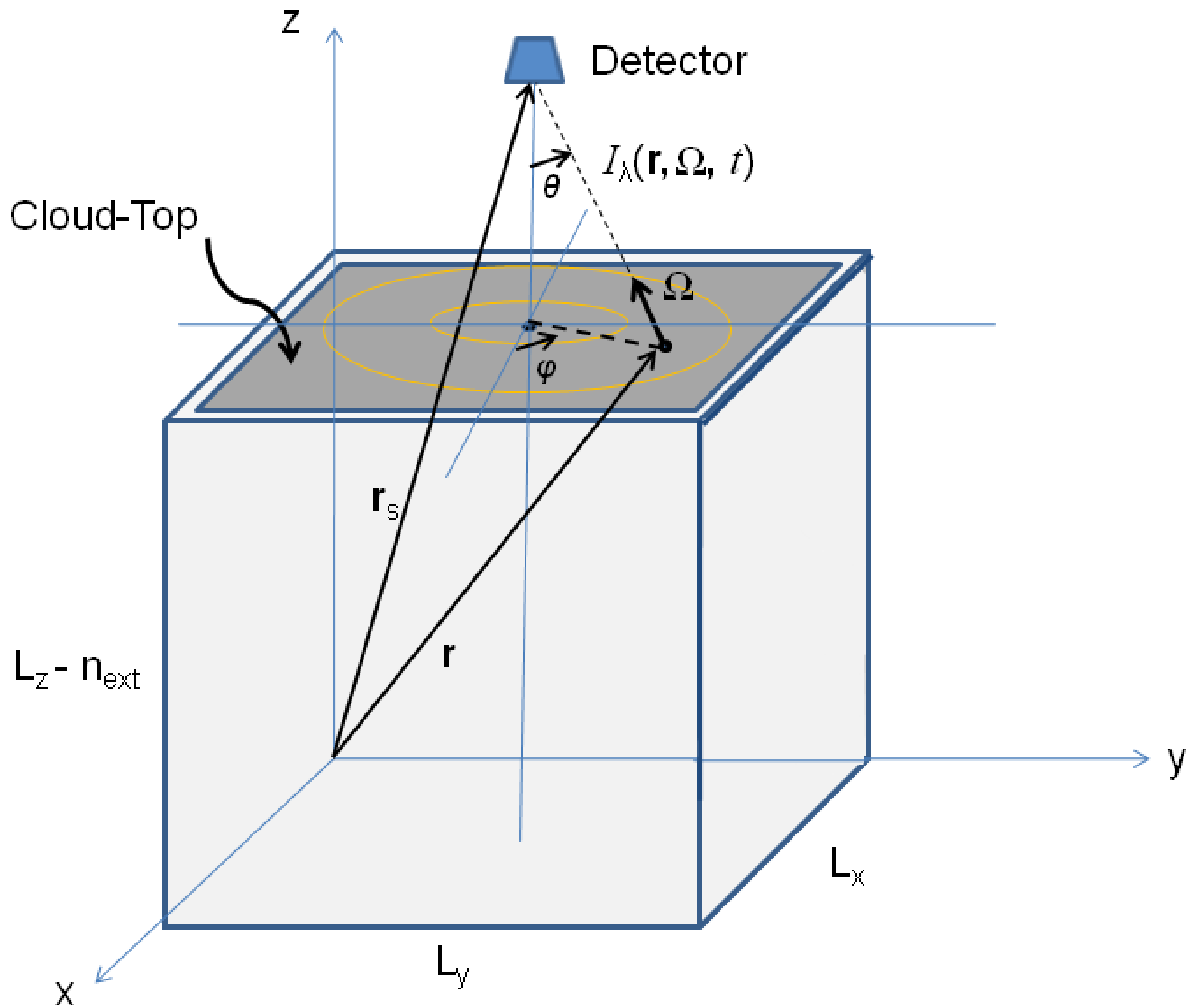


Figure 3. Geometry involved with computing the radiant energy received by a detector from the diffuse, transient lightning cloud-top emission. Note that the cloud is embedded within the solution space volume $V = L_x L_y L_z$ and the top vertical layer of the solution space, having thickness n_{ext}, has been removed for clarity. The point shown on cloud-top is $\mathbf{r}$ = (x, y, h), and the detector is located at $\mathbf{r}_s = (x_s, y_s, z_s)$.

Optical Energy Intercepted by Imager

$$\mathcal{G}(\mathbf{r},\mathbf{\Omega},t;\boldsymbol{\beta},\tau)=\frac{2}{\pi V}\sum_{l,m,n}\left[\psi_{lmn}(\mathbf{r})-\frac{3D}{c}\mathbf{\Omega}\cdot\nabla\psi_{lmn}(\mathbf{r})\right]\psi_{lmn}(\boldsymbol{\beta})e^{-\lambda_{lmn}^{2}(t-\tau)}H(t-\tau).$$

$$I_{\lambda}(\mathbf{r},\mathbf{\Omega},t)=\int\mathcal{G}(\mathbf{r},\mathbf{\Omega},t;\boldsymbol{\beta},\tau)\,S_{\lambda}(\boldsymbol{\beta},\tau)\,d\sigma\quad,$$

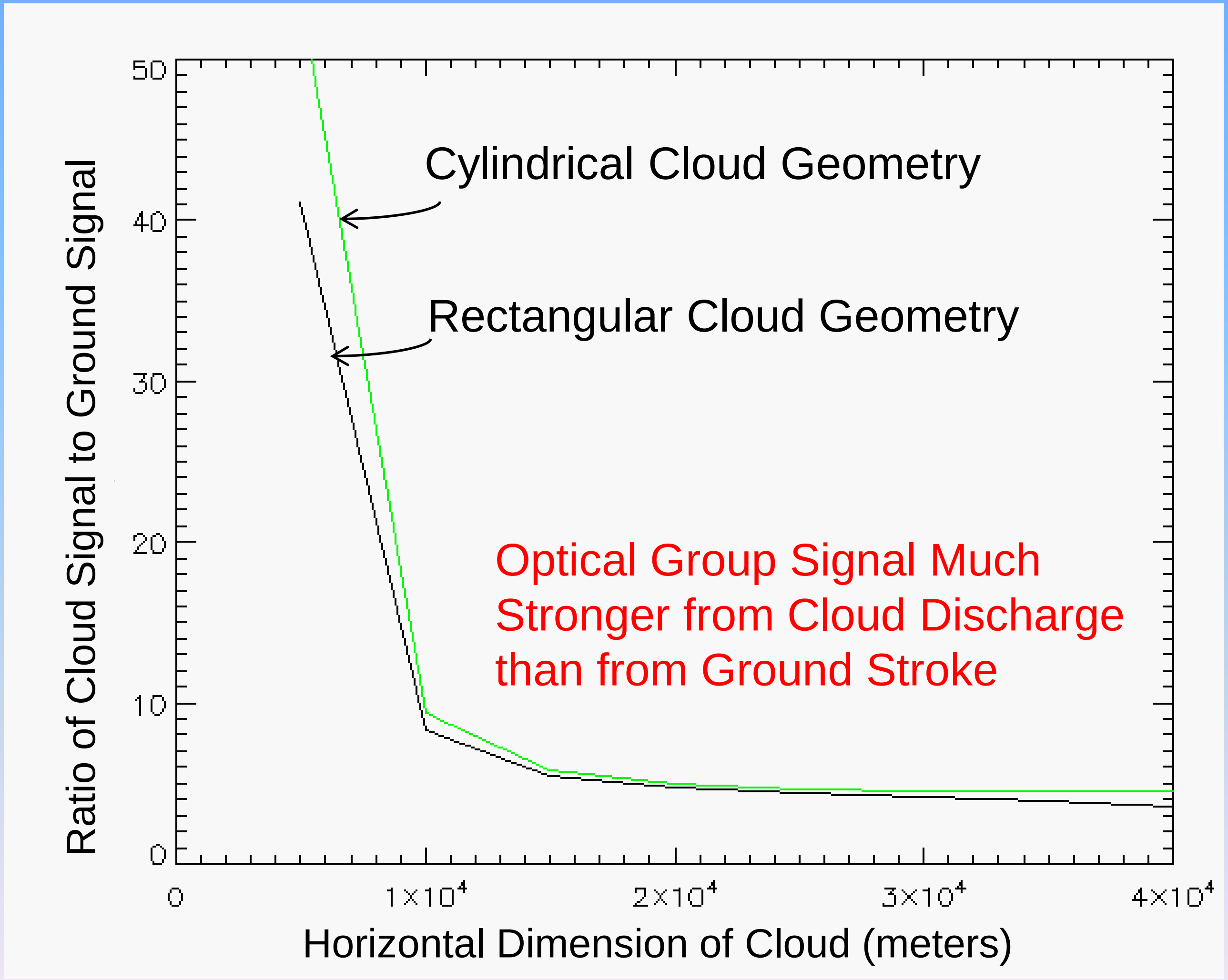
$$E=\int_{\Delta t}\int_{\Delta\Omega}\int_{\Delta\lambda}Q_{\lambda}(\theta,\varphi)\mathrm{K}_{\lambda}(\theta,\varphi)I_{\lambda}(\theta,\varphi,t)A(\theta)\,d\lambda\, d\Omega\, dt.$$

$A(\theta)=\pi R^{2}\cos\theta=$ Effective entrance aperature area,

$Q_{\lambda}(\theta,\varphi)=$ Spectral quantum efficiency of a point on the CCD array,

$\mathrm{K}_{\lambda}(\theta,\varphi)=$ Lens/filter system attenuation.

Preliminary Model Results (uncorrected integral)



Summary

- Discrimination difficult due to overlap in OTD flash-level measurements.
- Overlap due to:
  - Variability in lightning source
  - Variability in cloud properties
  - Difficulties in Partitioning OTD data into CGs & ICs
- No "smoking guns" found yet that would help to consistently discriminate CGs from ICs.
  - But, group brightness falls-off in CGs, not ICs.
- Additional <u>Data Mining</u> (at group & event level) and <u>Modeling</u> required to determine if discrimination possible.